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INVESTIGATION OF THE SUSCEPTIBILITY OF AN  
EXPERIMENTAL EXPLODING BRIDGE WIRE EXPLOSIVE  
INITIATOR TO ELECTROMAGNETIC ENERGY

by

W. L. Gilbertson



U. S. NAVAL WEAPONS LABORATORY  
DAHLGREN, VIRGINIA

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Dahlgren, Virginia

Investigation of the Susceptibility of an  
Experimental Exploding Bridge Wire  
Explosive Initiator to Electromagnetic Energy (U)

by

W. L. Gilbertson  
Weapons Development and Evaluation Laboratory

NWL Report No. 1772

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ABSTRACT

An experimental exploding bridge wire initiator has been designed by Picatinny Arsenal under MIPR 1-60 from the U. S. Naval Weapons Laboratory, Dahlgren. This initiator was developed as part of a continuing program to devise methods to protect modern ordnance systems from inadvertent actuation by electromagnetic radiation. Tests were conducted to determine the susceptibility of this item to initiation by electromagnetic energy.

The tests demonstrated that while the initiators could not be fired in a normal fashion (by exploding the bridge wire) by radio frequency energy fields encountered in present service conditions, the units could be initiated by cook-off following burn out of the bridging wire. Actuation in this manner is due primarily to dielectric heating in the nylon dielectric material.

It is recommended that the nylon be replaced with a more suitable material before any further electromagnetic energy susceptibility tests are conducted.

FOREWORD

This report describes tests of the susceptibility of an experimental explosive initiator to electromagnetic energy. A test program to determine hazards of electromagnetic radiation to ordnance (HERO) and the development of solutions to the problems associated with the phenomenon was assigned the U. S. Naval Weapons Laboratory by Task Assignments No. 992-918/80004/01-064 and No. RREN 03-001/210-1/F008-01-014, references (a) and (b).

This report was reviewed by the following personnel of the Weapons Development and Evaluation Laboratory:

L. W. PRUETT, Head, Research Branch  
Electromagnetic Hazards Division  
C. F. FADELEY, LCDR, USN, Electromagnetic Radiation Officer  
Electromagnetic Hazards Division  
J. N. PAYNE, Head, Electromagnetic Hazards Division  
D. W. STONER, Deputy Director  
Weapons Development and Evaluation Laboratory  
M. W. WHITAKER, Captain, USN, Director

APPROVED FOR RELEASE:

/s/ R. H. LYDDANE  
Technical Director

## INTRODUCTION

Modern ordnance employs large numbers of electrically initiated explosive devices for diverse functions ranging from ignition of rocket propellant or of destructive explosive loads to actuation of small valves or switches in complex control systems. The use of these electro-explosive devices (EEDs) has been restricted in some measure by the susceptibility of certain types to inadvertent actuation by radio frequency energy. The exploding bridge wire type of EED requiring high energy for initiation has been suggested as a possible means of eliminating these inadvertent actuations.

A Military Interdepartmental Purchase Request (I-60) to Commanding Officer, Picatinny Arsenal was issued in August 1959 by the Commander, U. S. Naval Weapons Laboratory, for a study to determine if the exploding bridge wire technique could be applied to the design of an EED less sensitive to rf energy than a conventional EED. Picatinny Arsenal was requested to design an exploding bridge wire device similar in physical and output characteristics to the Mk 2 Mod 2 ignition element and to produce a sufficient quantity of these devices for an adequate determination of its reactions to rf energy.

This report describes certain tests of the device conducted at the Denver Research Institute, Denver, Colorado, and at the Naval Weapons Laboratory.

## DESCRIPTION OF THE EXPERIMENTAL EBW INITIATOR

The exploding bridge wire initiator tested in this program was designed for use as a replacement for the Mk 2 Mod 2 ignition element in the Mk 171 igniter. The Mk 2 Mod 2 ignition element was modified by replacing the double bridge wire with a single bridge wire of 99.9 percent pure gold, 0.073 inches in length and 0.0015 inches in diameter. The insulation between the center electrode and inner and outer cups was replaced with nylon. The primary explosive was omitted and the element was loaded with 80 mg of pentaerythritol tetranitrate (PETN). Figures 1A and 1B show these modifications. Figure 1B also shows that the secondary explosive surrounds the bridge wire in the modified units.

The gold bridging wire of the modified ignition element has an electrical resistance of about 0.02 ohms. A fully loaded element, less bridge wire, exhibits an electrical capacity of about 8 pf between the



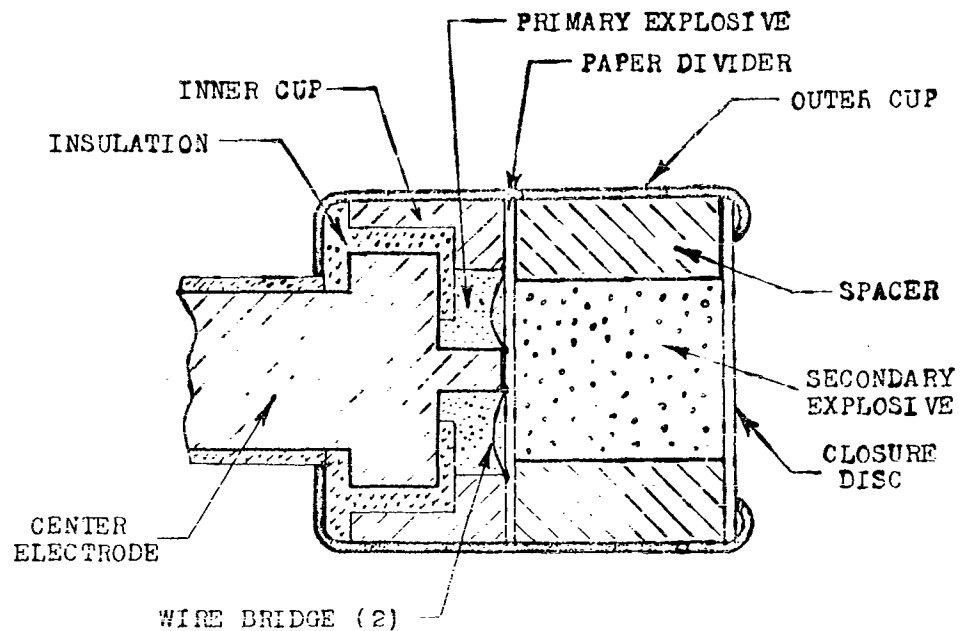


Figure 1A. IGNITION ELEMENT MK 2 MOD 2

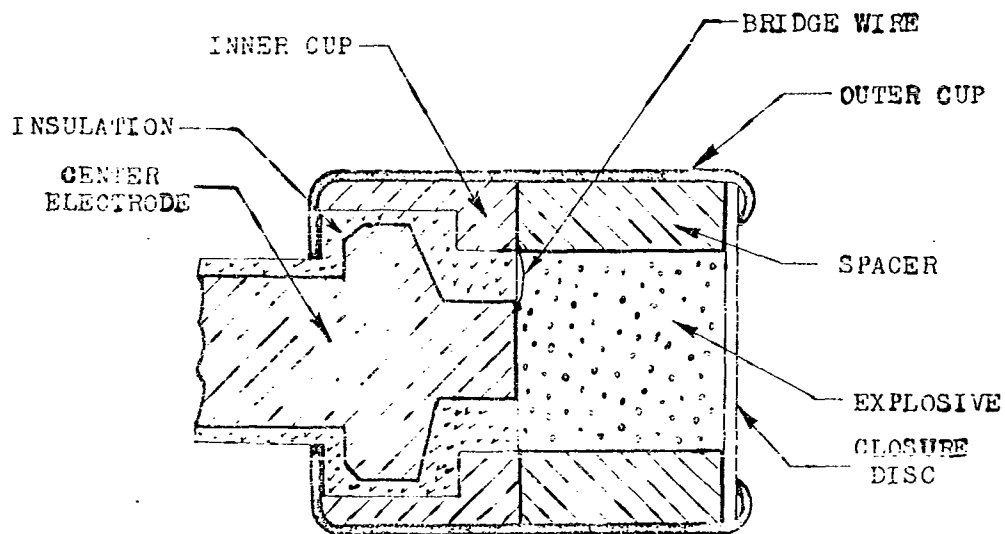


Figure 1B. MODIFIED (EBW) IGNITION ELEMENT MK 2 MOD 2

center electrode and the remainder of the element at room temperature. As the temperature of the unit rises during dud cook-off (as described later in this report) the capacity increases to as much as 23 pf.

#### TESTS OF INITIATION WITH CAPACITOR DISCHARGE

A limited number of samples of modified ignition elements were subjected to capacitor discharge tests at NWL, Dahlgren. These tests were conducted to determine if firing requirements were within practicable limits, and to determine if test fixtures were satisfactory for further tests. The following data were obtained:

<u>No. of Samples</u>	<u>Voltage</u>	<u>Capacitor Size</u>	<u>Result</u>
1	1500	1 $\mu$ fd	Fired
1	1000	1 $\mu$ fd	Fired
1	750	1 $\mu$ fd	Fired

Earlier tests of a limited number of samples at the Denver Research Institute produced the following data:

<u>No. of Samples</u>	<u>Voltage</u>	<u>Capacitor Size</u>	<u>Result</u>
6	1500	2 $\mu$ fd	Fired
1	1500	1 $\mu$ fd	Fired
1	1015	2 $\mu$ fd	Fired
1	1000	4 $\mu$ fd	Dudded
1	800	8 $\mu$ fd	Dudded
1	530	8 $\mu$ fd	Dudded

Bruceston tests of the modified ignition element reported by Picatinny Arsenal indicated a 50% fire point with a 1  $\mu$ fd capacitor charged to 750 volts. The recommended value for reliable firing is a 1  $\mu$ fd capacitor charged to 1500 volts.

TESTS OF INITIATION OF DUDS WITH A CAPACITOR DISCHARGE

Tests were conducted at the Naval Weapons Laboratory to determine if a dud unit; i.e., one whose bridge wire had burned out without firing the unit, could be initiated with a capacitor discharge. The following data were obtained:

<u>Round No.</u>	<u>Voltage (Volts)</u>	<u>Capacitor Size (<math>\mu</math>f)</u>	<u>Action</u>
1	1000	1	None
2	1000	2	None
3	1500	1	Partial Fire*
4	1500	2	Fired
5	1500	2	Partial Fire
6	2000	1	Partial Fire
7	2000	2	Partial Fire
8	3000	1	Partial Fire
9	3000	2	Partial Fire
10	4000	1	Fired

\*Partial fire indicates that part of the PETN explosive charge burned without igniting the remainder of the charge. Cases of the elements were distorted but not ruptured by this action.

In all capacitor discharge tests at Dahlgren a cable ten feet long connected the element to the firing source that was supplied by Picatinny Arsenal. A relay was employed to close the firing circuit.

TESTS OF INITIATION WITH RADIO FREQUENCY ENERGY

A standard AN/ART-13 radio transmitter was employed as a signal source for rf energy tests of the modified initiator. This transmitter has a nominal output of 100 watts at a frequency of 2 to 18.1 Mc, normally exciting a long wire antenna. In order to avoid problems involved in matching the output of this transmitter to a load of only 0.02 ohms dc resistance presented by the modified initiator, the unit under test was simply inserted as a series element in a tank circuit inductively coupled to the transmitter. Problems associated with calibrating the level of rf current in the system were thereby simplified to the insertion of a standard thermocouple type rf ammeter in series with the components. Figure 2A shows the system used.

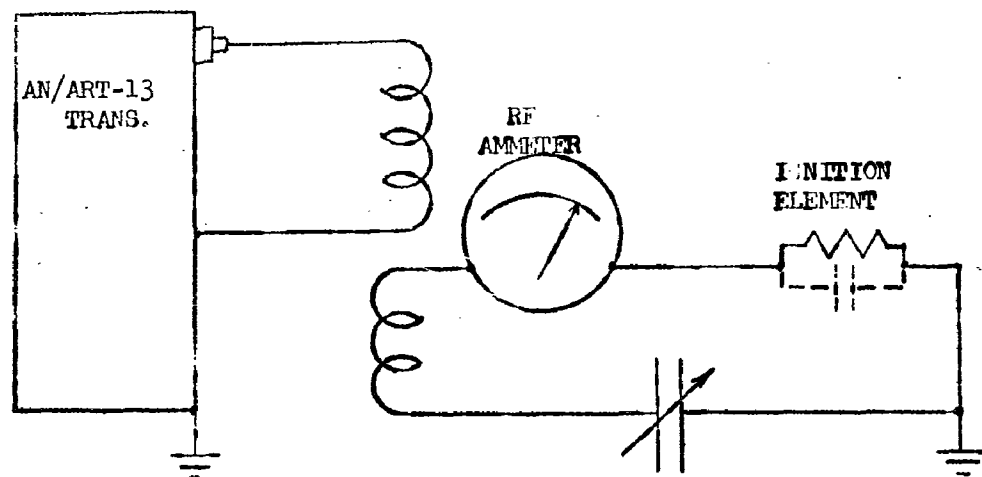


Figure 2A. CIRCUIT FOR HIGH CURRENT TESTS

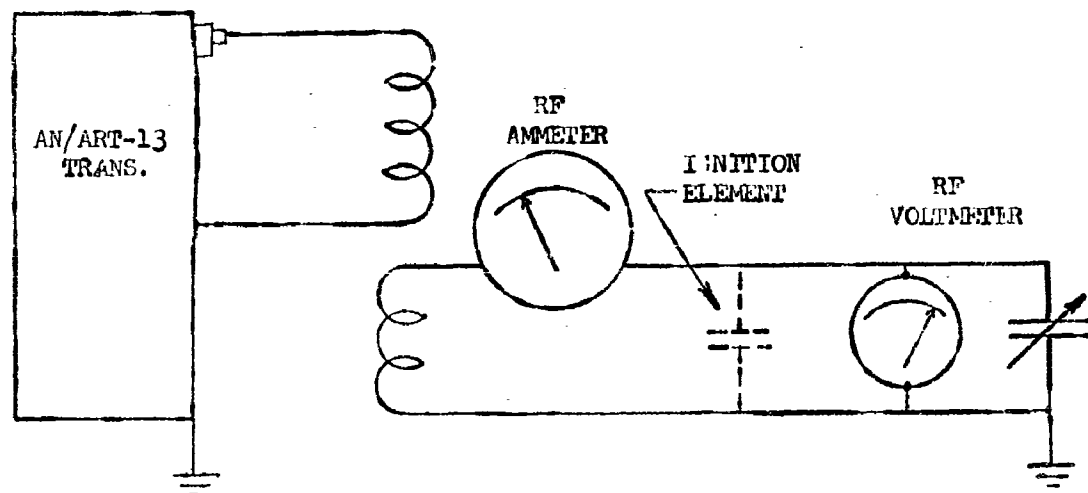


Figure 2B. CIRCUIT FOR HIGH VOLTAGE TESTS

Modified Mk 2 Mod 2 ignition elements were exposed to rf energy under three sets of conditions at frequencies from 5.5 Mc to 17.5 Mc. The conditions of exposure were:

- a. The units were exposed to 10 amperes CW until they fired or dudded.
- b. The current was increased from zero in 0.5 ampere steps at 30 second intervals until the units fired or dudded.
- c. The units were exposed to currents less than that required to dud them for 60 seconds and then the current was increased to 10 amperes (step function).

In each condition at every frequency employed in these tests, the modified units were dudded. In tests increasing the current in 0.5 ampere increments, this burnout occurred between 3.0 and 4.5 amperes.

#### TESTS OF INITIATION OF DUDS WITH RADIO FREQUENCY ENERGY

The original intent in attempts to fire dudded modified units with rf energy was to produce an rf arc of sufficient intensity through the PETN to initiate the unit. To this end the dudded unit was placed in a position electrically parallel with the variable capacitor in the tank circuit. It was noted that the "Q" of the circuit was significantly reduced when the modified unit was introduced, indicating the use of a relatively poor dielectric material. Figure 2B shows the system employed in these tests.

First attempts to produce an arc were made on a unit without the explosive, spacers, or cup so that the results could be observed. Application of rf energy quickly melted the nylon and forced it out of its normal position. The results shown in Figure 3 were produced by 1.4 amperes at a frequency of 16.22 Mc.

It was then apparent that no significant rf arc could be produced in dudded units at the frequencies involved, so attempts were made to cook-off loaded units with dielectric heating. (Nylon softens at approximately 160-200°C and PETN melts at about 140°C.)

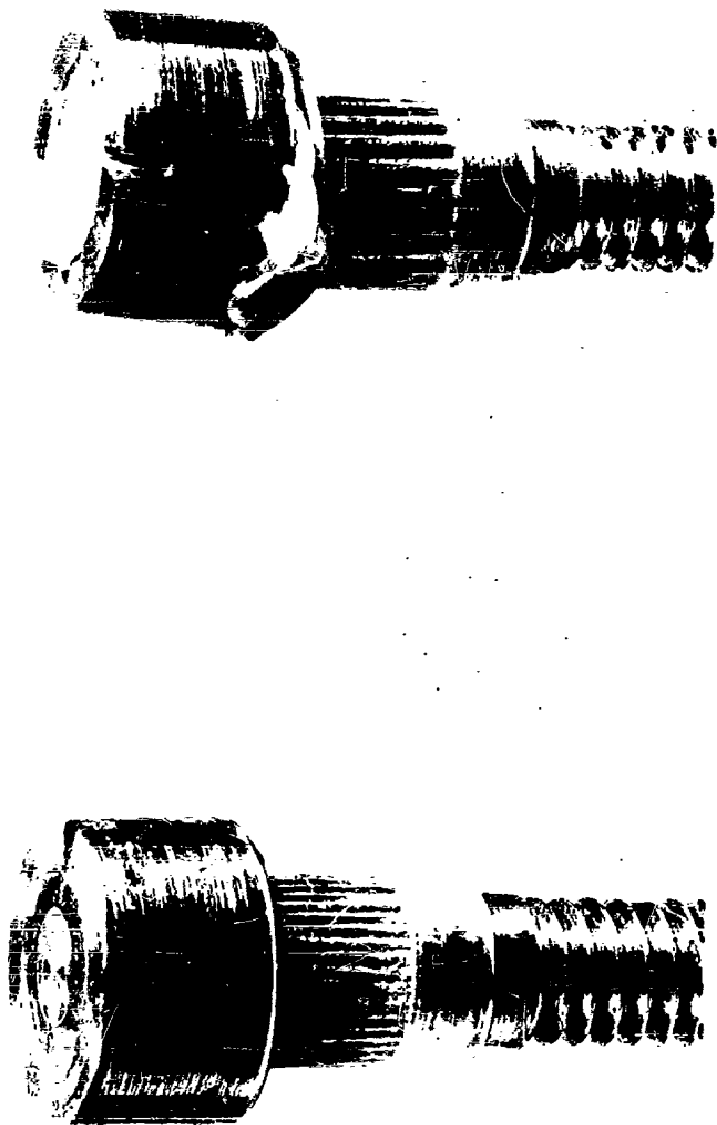
Most units tested showed significant breakdown of the nylon dielectric at about 170 volts rf. Several exhibited breakdown at lower values, and several required more than 200 volts. In most cases 135 volt-amperes was sufficient to cause initiation approximately 2 to 3 minutes after initial breakdown.

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Figure 3

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Basic 30' Structure Before and After Dielectric Heating. (12)



Initiation of the units by cook-off is a low order phenomenon. The initiation was sufficient to force the closure disc from the units, after which some test units burned with a candle-like flame for several seconds. Other test units splattered molten PETN around the firing chamber and produced no after-burn. In all instances a flash was observed by a photocell, apparently disproving the possibility that initiation was simply a bursting of the case from vapor pressure rather than an explosion or burning.

#### OVEN TESTS OF NYLON AND PETN

Open dish tests in a slowly heated oven added little information concerning the cook-off phenomenon. PETN was melted and boiling at about 150°C and had evaporated without any initiation by the time the oven temperature had reached 200°C. Powdered nylon had no apparent effect on PETN when the two were mixed, the PETN evaporating and the nylon eventually being destroyed, leaving a black ash.

#### DISCUSSION

The various tests described in this report indicate that the modified Mk 2 Mod 2 ignition element as conceived and produced by Picatinny Arsenal is unsuitable as a non-susceptible EED for use in an electromagnetic environment. Dudding of the element at 4 amperes and cook-off of the unit with 135 volt-amperes by dielectric heating make it unsuitable. These tests, however, have not demonstrated that the principle of an exploding wire initiation is unsound, but have indicated that the substitution of a more satisfactory dielectric material might be necessary to produce a usable item in this particular case.

This opinion, of course, is subject to verification by experiment, since the incorporation of a different dielectric material might make a dudded unit more susceptible to initiation by an rf arc. It is possible that ceramic, glass, or Teflon could be used as a dielectric material satisfactory for exploding bridge wire initiators.

Tests of the experimental exploding bridge wire initiator produced by Picatinny Arsenal were not completed. It was believed that little useful information could have been gained from further testing until the dielectric could be replaced with a more satisfactory material. The tests have served, however, to indicate a possible direction for subsequent EBW development.

### CONCLUSIONS

It is concluded that the experimental initiator tested in this program is not susceptible to normal initiation (exploding of the bridge wire) by electromagnetic fields of the intensity presently encountered in service conditions.

It is further concluded that a dudded unit, i.e., one whose bridge wire has been burned out without initiation, is susceptible to a low order initiation by electromagnetic energy. This phenomenon, caused by dielectric heating, and the relatively low current required for dudding limit the use of the modified ignition element in an electromagnetic environment.

### RECOMMENDATIONS

It is recommended that exploding bridge wire explosive initiators similar to those tested but capable of dissipating more power before dudding and utilizing a more satisfactory dielectric material be fabricated and subjected to tests to determine susceptibility to radio frequency energy. This dielectric material should withstand higher temperatures, and have a higher thermal conductivity.

### REFERENCES

- (a) Conf Task Assignment No. 992-918/80004/01-064 "EM Radiation Hazards (HERO)" of 9 Jul 1959
- (b) Conf Task Assignment No. RREN03-001/210-1/F008-01-014 "EM Radiation Hazards (HERO)" of 20 Jul 1960



## APPENDIX A

DISTRIBUTION

## HERO Distribution List III C

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<p>Naval Weapons Lab. (NWL Report No. 1772) INVESTIGATION OF THE SUSCEPTIBILITY OF AIR EXPERIMENTAL EXPLODING BRIDGE WIRE EXPLOSIVE INITIATOR TO ELECTROMAGNETIC ENERGY (U), by W. L. Gilbertson. 6 p., 5 figs.</p> <p>The exploding bridge wire initiator was developed as a part of a continuing program to devise methods to protect modern ordnance systems from inadvertent actuation by electromagnetic radiation. Tests demonstrated that while the initiators could not be fired in a normal fashion (by exploding the bridge wire) by radio frequency energy fields encountered in present service conditions, the units could be initiated by cook-off following burn out of the bridging wire. Actuation is due primarily to dielectric heating in the nylon dielectric material. It is recommended that the nylon be replaced with a more suitable material before any further electromagnetic energy susceptibility tests are conducted.</p>	<p>1. Electro-explosive devices 2. Exploding wire phenomena 3. Initiators - electromagnetic effects W. L. Gilbertson, W. L.</p> <p>Task: RREN03-001/210- IF008-01-014 UNCLASSIFIED</p>	<p>Naval Weapons Lab. (NWL Report No. 1772) INVESTIGATION OF THE SUSCEPTIBILITY OF AIR EXPERIMENTAL EXPLODING BRIDGE WIRE EXPLOSIVE INITIATOR TO ELECTROMAGNETIC ENERGY (U), by W. L. Gilbertson. 6 p., 5 figs.</p> <p>The exploding bridge wire initiator was developed as a part of a continuing program to devise methods to protect modern ordnance systems from inadvertent actuation by electromagnetic radiation. Tests demonstrated that while the initiators could not be fired in a normal fashion (by exploding the bridge wire) by radio frequency energy fields encountered in present service conditions, the units could be initiated by cook-off following burn out of the bridging wire. Actuation is due primarily to dielectric heating in the nylon dielectric material. It is recommended that the nylon be replaced with a more suitable material before any further electromagnetic energy susceptibility tests are conducted.</p>	<p>1. Electro-explosive devices 2. Exploding wire phenomena 3. Initiators - electromagnetic effects W. L. Gilbertson, W. L.</p> <p>Task: RREN03-001/210- IF008-01-014 UNCLASSIFIED</p>	<p>1. Electro-explosive devices 2. Exploding wire phenomena 3. Initiators - electromagnetic effects W. L. Gilbertson, W. L.</p> <p>Task: RREN03-001/210- IF008-01-014 UNCLASSIFIED</p>
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